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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7:		(1	1) International Publication Number:	WO 00/25002
E21B 43/24	A1	(4	3) International Publication Date:	4 May 2000 (04.05.00)
(21) International Application Number: PCT/CAS (22) International Filing Date: 26 October 1999 (2)			(81) Designated States: IN, RU, US, Eur CY, DE, DK, ES, FI, FR, GB, OPT, SE).	
(30) Priority Data: 2,251,157 26 October 1998 (26.10.98)	C	CA	Published With international search report.	
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(54) Title: PROCESS FOR SEQUENTIALLY APPLYIN	G SAC	GD	TO ADJACENT SECTIONS OF A PETRO	OLEUM RESERVOIR

## (57) Abstract

Steam assisted gravity drainage ("SAGD") is practised in a first section of a reservoir containing heavy oil. When production becomes uneconomic, steam injection into the first section is terminated. Non-condensible gas is then injected into the section to pressurize it and production of residual oil and steam condensate is continued. Concurrently with pressurization, SAGD is practised in an adjacent reservoir section. As a result, some of the residual oil in the first section is recovered and steam loss from the second section to the first section is minimized.

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### PROCESS FOR SEQUENTIALLY APPLYING SAGD TO ADJACENT

## SECTIONS OF A PETROLEUM RESERVOIR

## FIELD OF THE INVENTION

This invention relates to recovering heavy oil from an underground reservoir using a staged process involving, in the first stage, steam assisted gravity drainage, and in the second stage, non-condensible gas injection and reservoir pressurization.

## BACKGROUND OF THE INVENTION

Steam assisted gravity drainage ("SAGD") is a process first proposed by R. M. Butler and later developed and tested at the Underground Test Facility ("UTF") of the Alberta Oil Sands Technology and Research Authority ("AOSTRA"). The SAGD process was originally developed for use in heavy oil or bitumen containing reservoirs, (hereinafter collectively referred to as 'heavy oil reservoirs'), such as the Athabasca oil sands. The process, as practised at the UTF, involved:

Drilling a pair of horizontal wells close to the base of the reservoir containing the heavy oil. One well was directly above the other in relatively close, co-extensive, spaced apart, parallel relationship.
 The wells were spaced apart 5 – 7 meters and extended in parallel horizontal relationship through several hundred meters of the oil pay or reservoir;

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• Then establishing fluid communication between the wells so that fluid could move through the span of formation between them. This was done by circulating steam through each of the wells to produce a pair of "hot fingers". The span between the wells warmed by conduction until the contained oil was sufficiently heated so that it could be driven by steam pressure from one well to the other. The viscous oil in the span was replaced with steam and the wells were then ready for production;

Then converting to SAGD production. More particularly, the upper well was used to inject steam and the lower well was used to produce a product mixture of heated oil and condensed water. The production well was operated under steam trap control. That is, the production well was throttled to maintain the production temperature below the saturated steam temperature corresponding to the production pressure. Otherwise stated, the fluids being produced at the production interval should be at undersaturated or "subcooled" condition. (Subcool = steam temperature corresponding to the measured producing production pressure – measured temperature.) This was done to ensure a column of liquid over the production well. to minimize "short-circuiting" by injected steam into the production well. The injected steam began to form an upwardly enlarging steam chamber in the reservoir. The chamber extended along the length of the horizontal portions of the well pair. Oil that had originally filled the chamber sand was heated, to mobilize it, and

drained, along with condensed water, down to the production well, through which they were removed. The chamber was thus filled with steam and was permeable to liquid flow. Newly injected steam moved through the chamber and supplied heat to its peripheral surface, thereby enlarging the chamber upwardly and outwardly as the oil was mobilized and drained together with the condensed water down to the production well.

This process is described in greater detail in Canadian patent 1,304,287 (Edmunds, Haston and Cordell).

The process was shown to be commercially viable and is now being tested by several oil companies in a significant number of pilot projects.

Now, the operation of a single pair of wells practising SAGD has a finite life. When the upwardly enlarging steam chamber reaches the overlying, cold overburden, it can no longer expand upwardly and heat begins to be lost to the overburden. If two well pairs are being operated side by side, their laterally expanding chambers will eventually contact along their side edges and further oil-producing lateral expansion comes to a halt as well. As a result, oil production rate begins to drop off. As a consequence of these two occurrences, the steam/oil ratio ("SOR") begins to rise and continued SAGD operation with the pair eventually becomes uneconomic.

If one considers two side-by-side SAGD well pairs which have been produced to "maturity", as just described, it will be found that a ridge of unheated oil is left between the well pairs. It is of course desirable to minimize this loss of unrecovered oil.

In Canadian patent 2,015,460 (Kisman), assigned to the present assignee, there is described a technique for limiting the escape of steam into a thief zone. For example, if steam is being injected into a relatively undepleted reservoir section and there is a nearby more depleted reservoir section, forming a low pressure sink, there is a likelihood that pressurized steam will migrate from the undepleted section into the more depleted section – which is an undesired result. One wants to confine the steam to the relatively undepleted section where there is lots of oil to be heated, mobilized and produced. The Kisman patent teaches injecting a non-condensible gas, such as natural gas, into the more depleted section to raise its pressure and equalize it with the pressure in the relatively undepleted section. By this means, the loss of steam from the one section to the other can be curtailed or minimized.

The Kisman patent further teaches that pressurizing the more depleted section with natural gas has been characterized by an increase in production rate from that section, if the production well penetrating the section is produced during pressurization.

## **SUMMARY OF THE INVENTION**

In accordance with the present invention, a novel process is provided for producing adjacent sections of an underground reservoir containing heavy oil. Each section is penetrated by one or more wells completed for SAGD operation, preferably one or more pairs of horizontal injection and production wells. The process comprises:

1	(a)	injecting steam into the first section of the reservoir to practice
2		SAGD and produce contained oil, until the steam/oil ratio rises
3		sufficiently so that further production by SAGD from the section
4		is substantially uneconomic;
5	(b)	then reducing or terminating steam injection into the first section
6		and injecting non-condensible gas into the section to maintain it
7		pressurized;
8	(c)	continuing to produce oil from the first section while it is
9		pressurized; and
10	(d)	concurrently with step (c), injecting steam into the adjacent
11		second section to practice SAGD therein and produce contained
12		oil;
13	(e)	while preferably maintaining the first section pressurized to
14		substantially the same pressure as exists in the second section
15		during step (d).
16	Steps	(b) and (c) constitute a post-steam wind-down of oil production
17	from the first	section. Over time, oil production rate will drop off during wind-
18	down and ev	rentually it will again become uneconomic to justify continuing to
19	produce the	first section. However it may still be desirable to continue
20	maintaining	pressurization in the first section to limit steam loss from the
21	second section	on.

The process provides a strategy for sequentially producing adjacent sections across the reservoir. It takes advantage of gas pressurization to prevent steam leakage from a less depleted section undergoing SAGD to a mature, more depleted section. It also maximizes production from each section by subjecting it to sequential SAGD and pressurization production stages.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

In accordance with the best mode of the process known to the applicants, it comprises:

- (a) directionally drilling one or more pairs of wells from ground surface into a reservoir first section, to provide generally parallel, horizontal, co-extensive, spaced apart, upper and lower well portions extending through the section, and completing the wells for SAGD production;
- (b) establishing fluid communication between the injection and production wells of each pair, for example by circulating steam through both wells, to heat the span between the wells by heat conduction, and then displacing and draining the oil in the span by injecting steam through the upper injection well and opening the lower production well for production;

1	(C)	practising SAGD in the reservoir first section by injecting steam
2		through the injection wells and producing the produced heated
3		oil and condensed water through the production wells while
4		operating said production wells under steam trap control;
5	(d)	preparing a second adjoining section of the reservoir for SAGD
6		production by carrying out the provision of wells and establishing
7		fluid communication between the wells of each pair as in steps
8		(a) and (b);
9	(e)	terminating or reducing steam injection into the reservoir first
10	•	section injection wells and initiating natural gas injection through
11		said injection wells to increase the pressure in the reservoir first
12		section to about the anticipated steam injection pressure in the
13		reservoir second section and maintaining the pressure at about
14		this level while simultaneously producing residual heated oil and
15		steam condensate through the production wells under steam
16		trap control; and
17	(f)	concurrently with step (e), practising SAGD in the reservoir
18		second section.
19	In cor	nnection with practising steam trap control with wells extending
20	down from	ground surface and having riser and horizontal production
21	sections, it is	preferred to operate as follows:
22	• me	easuring the downhole temperature at the injection and
23	pro	oduction wells of an operating pair, using thermocouples;

1 · establishing the temperature differential between the two wells and 2 throttling the production well to maintain the differential at a 3 generally constant value (say 7°); 4 monitoring for significant surges in vapour production rate at the 5 ground surface production separator and for surges in steam 6 injection rate; and 7 adjusting throttling to minimize the surges. 8 Otherwise stated, a generally constant liquid rate at the wellhead is 9 maintained and the bottomhole production temperature is allowed to vary 10 within a limited range. 11 The invention is characterized by the following advantages: 12 additional oil is recovered from the mature wells during the gas 13 pressurization stage, while simultaneously reducing steam leakage 14 from the second reservoir section; 15 • use is made of the residual heat left in the mature reservoir section; 16 and 17 a finite steam-producing plant can be applied in sequence to a 18 plurality of adjacent sections of the reservoir, without severe steam

loss from a section undergoing SAGD to an adjacent depleted

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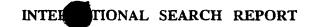
section.

1	THE EMBODIMENTS OF THE INVENTION IN WHICH AN
2	EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS
3	FOLLOWS:
4	1. A method for recovering heavy oil from an underground reservoir
5	comprising:
6	(a) injecting steam and producing heated oil and steam condensate
7	by steam assisted gravity drainage ("SAGD") in a first section of the reservoir
8	until it is substantially uneconomic to continue doing so;
9	(b) preparing an adjoining section of the reservoir for SAGD;
10	(c) terminating or reducing steam injection into the reservoir first
11	section;
12	(d) injecting steam and producing heated oil and steam condensate
13	by SAGD in an adjacent second section of the reservoir; and
14	(e) concurrently with step (d), injecting a non-condensible gas into
15	the first section to pressurize it and producing residual oil and steam
16	condensate from said first section.
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18	2. The method as set forth in claim 1 wherein:
19	the first section is pressurized in step (e) to a pressure about equal with
20	the steam injection pressure in step (d).

#### TIONAL SEARCH REPORT INTE

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A CLASSI IPC 7	FICATION OF SUBJECT MATTER E21B43/24		
According to	o international Patent Classification (IPC) or to both national classific	cation and IPC	
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	tion searched other than minimum documentation to the extent that		
Electronic d	ata base consulted during the International search (name of data b	ase and, where practical	search terms used)
C. DOCUM	ENTS CONSIDERED TO BE RELEVANT		
Category °	Citation of document, with indication, where appropriate, of the re	elevant passages	Relevant to claim No.
Y	CA 2 015 460 C (KISMAN KENNETH E 26 October 1991 (1991-10-26) cited in the application page 4, line 6 - line 18 page 9, line 7 - line 18	)	1,2
Υ	GB 1 463 444 A (SHELL INTERNATIO RESEARCH MAATSHAPPIJ) 2 February 1977 (1977-02-02) page 1, line 63 - line 92	NALE	1,2
A	US 4 903 768 A (SHU PAUL) 27 February 1990 (1990-02-27) column 2, line 44 - line 61	,	1
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X Fur	ther documents are listed in the continuation of box C.	X Patent family	members are listed in annex.
* Special co	ategories of cited documents:	"T" later document pu	blished after the international filing date of not in conflict with the application but
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	than the priority date claimed actual completion of the international search		r of the same patent family the international search report
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	NL - 2290 HV Rijewijk Tel. (+31-70) 340-2040, Tx. 31 651 epo ni, Fax: (+31-70) 340-3016	Garrid	o Garcia, M

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	ation) DOCUMENTS CONSIDERED TO BE RELEVANT	<del></del>	154
Category °	Citation of document, with indication, where appropriate, of the relevant passages		Relevant to claim No.
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A	column 1, line 49 - line 65 column 2, line 66 -column 3, line 16 US 5 318 124 A (ONG TEE S ET AL) 7 June 1994 (1994-06-07)		1

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Information on patent family members

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US 5318124	A	07-06-1994	CA DE RU	2055549 A 4238247 A 2098613 C	15-05-1993 19-05-1993 10-12-1997



## **PATENT COOPERATION TREATY**

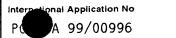
## PCT

## INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference			Transmittal of Interna 0) as well as, where a	tional Search Report pplicable, item 5 below.
1024.106 International application No.	International filing date (day	/month/year)	(Earliest) Priority Da	te (day/month/year)
PCT/CA 99/00996	26/10/199		26/1	10/1998
Applicant	<u> </u>			
ALBERTA OIL SANDS TECHNOL	OGY ANDet al.			
This International Search Report has bee according to Article 18. A copy is being tra	n prepared by this Internation ansmitted to the International	al Searching Autho Bureau.	ority and is transmitted	d to the applicant
This International Search Report consists  X It is also accompanied by	of a total of3 a copy of each prior art docu	sheets. ment cited in this r	eport.	
Basis of the report				
a. With regard to the language, the language in which it was filed, un	international search was carr less otherwise indicated unde	ied out on the basi r this item.	s of the international a	application in the
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the statement that the inf furnished	ormation recorded in compute	er readable form is	identical to the writer	n sequence listing has been
2. Certain claims were fou	ınd unsearchable (See Box I	).		
3. Unity of invention is lac	cking (see Box II).			
4. With regard to the title,				
1 = ''	ubmitted by the applicant.			
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	ubmitted by the applicant.			
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6. The figure of the drawings to be put	olished with the abstract is Fig	jure No.		
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because this figure bette	er characterizes the invention.			

## INTERNATIONAL SEARCH REPORT

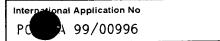


			A 99/00996		
A. CLASSIF IPC 7	ECATION OF SUBJECT MATTER E21B43/24				
According to	International Patent Classification (IPC) or to both national classification	ion and IPC			
B. FIELDS					
	cumentation searched (classification system followed by classification	ı symbols)			
Documentati	ion searched other than minimum documentation to the extent that suc	ch documents are inclu	ided in the fields searched		
Electronic da	ata base consulted during the international search (name of data base	e and, where practical	search terms used)		
C. DOCUME	ENTS CONSIDERED TO BE RELEVANT				
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Y	CA 2 015 460 C (KISMAN KENNETH E) 26 October 1991 (1991-10-26) cited in the application page 4, line 6 - line 18 page 9, line 7 - line 18		1,2		
Y	GB 1 463 444 A (SHELL INTERNATION RESEARCH MAATSHAPPIJ) 2 February 1977 (1977-02-02) page 1, line 63 - line 92	ALE	1,2		
A	US 4 903 768 A (SHU PAUL) 27 February 1990 (1990-02-27) column 2, line 44 - line 61		1		
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"A" docume consider filing of the country of the co	ent defining the general state of the art which is not dered to be of particular relevance document but published on or after the international date ent which may throw doubts on priority claim(s) or is cited to establish the publication date of another in or other special reason (as specified) sent referring to an oral disclosure, use, exhibition or means ent published prior to the international filing date but	or priority date ar cited to understal invention  "X" document of partic cannot be consid involve an invent  "Y" document of partic cannot be consid document is com ments, such com in the art.	blished after the international filing date and not in conflict with the application but and the principle or theory underlying the sular relevance; the claimed invention ered novel or cannot be considered to ve step when the document is taken alone sular relevance; the claimed invention ered to involve an inventive step when the bined with one or more other such docubination being obvious to a person skilled		
<u></u>	later than the priority date claimed "&" document member of the same patent family				
	actual completion of the international search  7 January 2000	28/01/2			
	mailing address of the ISA  European Patent Office, P.B. 5818 Patentlaan 2	Authorized officer			
	NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Garrid	o Garcia, M		

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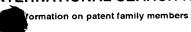
## INTERNATIONAL SEARCH REPORT





C.(Continua	tion) DOCUMENTS CONSIDERED TO BE RELEVANT	
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 166 504 A (BROWN ALFRED ET AL) 4 September 1979 (1979-09-04) column 1, line 49 - line 65 column 2, line 66 -column 3, line 16	1
A	US 5 318 124 A (ONG TEE S ET AL) 7 June 1994 (1994-06-07)	
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## INTERNATIONAL SEARCH REPORT



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PCA	99/00996	

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US 5318124	Α	07-06-1994	CA DE RU	2055549 A 4238247 A 2098613 C	15-05-1993 19-05-1993 10-12-1997	



### From the INTERNATIONAL BUREAU

## **PCT**

### **NOTIFICATION OF ELECTION**

(PCT Rule 61.2)

0.

Assistant Commissioner for Patents United States Patent and Trademark Office Box PCT Washington, D.C.20231

Date of mailing (day/month/year)
20 June 2000 (20.06.00)

International application No.
PCT/CA99/00996

International filing date (day/month/year)
26 October 1999 (26.10.99)

Applicant

GOOD, William, Keith et al

1.	The designated Office is hereby notified of its election made:								
	X in the demand filed with the International Preliminary Examining Authority on:								
	24 May 2000 (24.05.00)								
	in a notice effecting later election filed with the International Bureau on:								
2.	The election X was								
	made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).								

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Authorized officer

Manu Berrod

Telephone No.: (41-22) 338.83.38

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## PATENT COOPERATION TREA



REC'D 15 NOV 2000

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## INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

1024.106	Proliminary Examination Report (Form Form Examination								
International application No.	International filing date (da	ay/month/year)	Priority date (day/month/year)						
PCT/CA99/00996	26/10/1999		26/10/1998						
International Patent Classification (IPC) or national classification and IPC E21B43/24									
Applicant									
ALBERTA OIL SANDS TECHNOLOGY ANDet al.									
This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.									
2. This REPORT consists of a total of	4 sheets, including this	cover sheet.							
This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT). These annexes consist of a total of 1 sheets.									
This report contains indications relations	3. This report contains indications relating to the following items:								
! ⊠ Basis of the report									
II ☐ Priority									
		velty, inventive step and industrial applicability							
IV  Lack of unity of invention		the description of the state of							
V   Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement									
VI   Certain documents cit									
VII 🖾 Certain defects in the i									
VIII 🗵 Certain observations on the international application									
Date of submission of the demand	,	Date of completion of	etion of this report						
24/05/2000		13.11.2000							
Name and mailing address of the internation preliminary examining authority:	al	Authorized officer	Gentles M. C. Viet M.						
European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 52365	56 epmu d	Tompouloglou, C							
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Applicant's or agent's file reference

# INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/CA99/00996

-		is of the report					
1.	This report has been drawn on the basis of (substitute sheets which have been fumished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).): Description, pages:						
	1-8		as originally filed				
	Clai	ims, No.:					
	1		with telefax of	25/10/2000			
2.	lang	guage in which the	international applicatio	s marked above were available or furnished to this Authority in the n was filed, unless otherwise indicated under this item.  o this Authority in the following language: , which is:			
	_		turn eletion furnished for	or the purposes of the international search (under Rule 23.1(b)).			
			translation furnished for	ational application (under Rule 48.3(b)).  or the purposes of international preliminary examination (under Rule			
3.	Wit inte	h regard to any <b>nu</b> ernational prelimina	<b>cleotide and/or amino</b> try examination was ca	acid sequence disclosed in the international application, the rried out on the basis of the sequence listing:			
		contained in the i	ntemational application	in written form.			
		filed together with	n the international appli	cation in computer readable form.			
		fumished subseq	uently to this Authority	in written form.			
				in computer readable form.			
		the international	application as filed has				
		The statement th listing has been f		rded in computer readable form is identical to the written sequence			
4.	The	e amendments hav	ve resulted in the cance	ellation of:			
		the description,	pages:				
		the claims,	Nos.:				
		the drawings,	sheets:				
5	. 🗆	This report has b considered to go	peen established as if (so beyond the disclosure	some of) the amendments had not been made, since they have beer as filed (Rule 70.2(c)):			



International application No. PCT/CA99/00996

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

- 6. Additional observations, if necessary:
- V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- 1. Statement

Novelty (N)

Yes:

Claims 1

No:

Claims

Inventive step (IS)

Claims 1

Yes: No:

Claims

Industrial applicability (IA)

Yes:

Claims 1

No: Claims

2. Citations and explanations see separate sheet

### VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

s e separate sheet

#### VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made: see separate sheet

Form PCT/IPEA/409 (Boxes I-VIII, Sheet 2) (July 1998)

## POINT V.

The claim is judged as an unambiguous assembly of its feature i.e under the assuption that the word "in" (see Point VIII) has been removed.

The preamble of the claim (text preceding the expression "the improvement comprising") corresponds to CA-A-2015460.

The characterising features of the claim solve the problem of optimising the strategy of sequential exploitation of the two sections of a reservoir because they result in the minimum possible loss of heat of the steam. Indeed that fact that the first section is also producing whilst non-condensible gas is injected in it mean that any possible loss of steam of the second section is exploited to the maximum due to the horizontal arrangement of the production and injection wells.

Although this arrangement is known from US-A-5318124, the step of the concurrent injection of the non condensible gas into the first section of the reservoir is not known from this document.

#### **POINT VII**

Following should have been taken into account:

- Rule 5.1 (a) ii) reference also to US'124 and their disclosure in the description.
- Rule 5.1 (a) iii) PCT: description in conformity with the new claims.

#### **POINT VIII**

The use of the word "in a method" makes it unclear whether protection is sought for the improvement only or for all the features defined in the claim. Therefore Article 6 is PCT infringed with regard to clarity.

THE	EMBODIMEN	TS	OF	THE	IM	VENTION	I	WHICH	AN
EXCLUSIVE	PROPERTY (	OR	PRIVIL	.EGE	IS C	ZLAIMED	ARE	DEFINED	AS
FOLLOWS:									

1. In a method for recovering heavy oil from an underground reservoir wherein a first section of the reservoir is at least partially depleted and an adjoining second section is less depleted, and wherein injected fluid can move from one section to the other, and wherein a non-condensible gas is injected into the first section while steam is injected into the second section so that the pressure in the two sections of reservoir is about equal, the improvement comprising:

the first section has been depleted by practising steam assisted gravity drainage ("SAGD") using one or more horizontal pairs of injection and production wells;

practising SAGD in the second section using one or more horizontal pairs of injection and production wells by injecting steam through the injection wells and producing oil and steam condensate through the production wells;

and concurrently injecting the non-condensible gas through the injection wells of the first section and producing oil through the production wells of the first section while maintaining the pressure in the two sections of reservoir about equal.